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MAINTAINING THE PERMISSIBILITY OF ELECTRIC CAP LAMPS

BY

D. H. ZELLERS AND A. B. HOOKER

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MAINTAINING THE PERMISSIBILITY OF ELECTRIC CAP LAMPS[1]

By D. H. Zellers[2] and A. B. Hooker[3]

INTRODUCTION

Since its inception the United States Bureau of Mines has fostered the development of portable mine lamps. Although there is still much to be desired with respect to illumination in coal and metal mines and the replacement of open lights has been slow, the Bureau has been given credit for assisting materially in the development and introduction of the safe and efficient portable mine-lighting equipment available today.

Much of the work conducted by the electrical section of the Bureau entails approval tests of various types of electrical equipment, including lamps, to be used in atmospheres that may contain methane or coal dust in explosive proportion. If a cap lamp meets the requirements for safety, efficiency, and adequacy, as published in Schedule 6B,[4] it is approved and is generally known as a "permissible" lamp. The terms "approved" and "permissible" often are used interchangeably. The manufacturer must put an approval plate on each approved lamp, showing it has met the schedule requirements. The approval plate is not a guarantee that the lamp is safe. However, if the lamp, once in service, has not had any parts changed or improperly assembled or if parts that wear out or depreciate have been properly replaced it should still be safe, efficient, and adequate for the service intended. Virtually all electric cap lamps in service today in the United States and a great many that have been sent to foreign countries bear the approval plate of the United States Bureau of Mines. Although many explosions have been attributed to open lights none has been charged against the permissible cap lamp. Nystagmus, a disease of the eye attributed to working under insufficient illumination, is practically unknown among American miners, although it is quite prevalent among European miners.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6832."

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[4] Bureau of Mines Permissible Electric Cap Lamps; Procedure in Testing, Fees Charged, and Requirements for Approval: Sched. 6B, December 1926, 7 pp.

The Bureau's first consideration is safety; to meet the schedule requirements an electric cap lamp must therefore embody a safety device designed to interrupt the electrical circuit should the bulb glass be broken and thereby eliminate the explosion hazard of an exposed glowing filament. Battery covers that are removed for charging must be equipped with magnetic or other equally effective locks; headpieces must also be equipped with a lock or seal to prevent the exposure of live terminals without unwarranted tampering. The battery must contain nonspilling devices to prevent the spillage of electrolyte from the vent plugs and possibly serious flesh burns or damage to clothing. The reflector must be designed and the bulb located to distribute the light properly without throwing objectionable dark spots or rings or causing undue strain on the eyes of the wearer or his fellow-workers.

Efficiency and adequacy are additional considerations. The bulbs supplied for use with cap lamps submitted for approval must meet requirements for life and physical, electrical, and photometric uniformity; the cord, battery case, and headpiece must meet requirements for mechanical strength and durability, and the battery must have sufficient capacity to supply ample energy throughout a full working shift.

There are two general ways of procuring cap lamps - rental and outright purchase. A large percentage of the newer lamps are on a rental basis. Although only a small percentage of lamps are purchased the data on maintenance of lamps apply particularly to such installations.

MAINTENANCE

Batteries

The battery is the power plant of the cap lamp. The maximum amount of light cannot be obtained unless the power plant is in perfect condition. Battery efficiency, therefore, is of first importance when efficiency of the lamp as a whole is under consideration. All permissible cap lamps are either of the alkaline or the lead-acid storage-battery type. The alkaline cap-lamp battery is relatively long-lived, having a rated life of 70 to 80 months; the rated life of the lead-acid battery is 18 to 24 months.

It should be understood that battery plates gradually deteriorate and that during the latter half of the normal life of a cap-lamp battery the capacity decreases considerably. As a result, the lamp gives less light, and usually the time of burning is reduced seriously. Loss of burning time can be compensated for by using lower-current bulbs, but the lamp still will give less light.

Charging.- The service obtained from a lamp battery depends much upon how it is charged. The charging rate should be enough to stimulate the necessary plate action yet not high enough to overheat or dislodge active plate material.

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The "constant-current method" generally is employed for charging alkaline batteries; the supply is usually of practically constant voltage, and a variable resistance is provided in the charging line. To maintain constant current this resistor must be readjusted periodically to maintain the supply voltage at a higher value than the increasing E.M.F. of the batteries. At each adjustment the current should be set a little above the normal value so that at the next adjustment the rate will not be much below normal, thus maintaining an average of the normal rate recommended by the manufacturer. The charging rate should always be that specified by the manufacturer, but the charge should be continued until 15 to 20 percent excess has been returned over and above the capacity taken from the battery during the previous discharge or until a maximum voltage has been reached and maintained for an appreciable time. The specific gravity of an alkaline battery does not change appreciably during charge, so gravity readings will not adequately indicate the state of charge; however, it can be determined with a voltmeter. The voltage of a fully charged alkaline battery will range from 1.80 to 1.90 volts per cell at the normal charging rate, depending on the temperature, age of cells, condition of electrolyte, etc., but this is of no consequence because the idea is to reach and maintain the normal maximum voltage. An abnormally high voltage reading indicates excessive resistance, which usually is due to poor contact between clip and battery posts but, if not, indicates high internal resistance in the battery assembly. An abnormally low voltage reading indicates that one cell probably is shorted between the valve and pole nut on the rack charging clip.

The constant-current method explained under charging of alkaline batteries may be employed for charging lead batteries, but the constant-potential or constant-voltage method is used quite generally in the newer installations. Constant-potential charging operates automatically and requires a minimum amount of attention and a shorter time for a complete charge. It also requires a source of constant voltage a little above the individual battery voltage, with a large enough current capacity to supply the number of batteries to be charged. Specially designed motor-generator sets, the generator of which has the desired characteristics, are available for this service. The constant-potential method of charging is especially suitable for lead-acid cap-lamp batteries. A battery can be put on charge in any state of discharge, and the charging rate will be controlled automatically at the proper values until the battery again becomes fully charged. Overcharging is impossible, except by increasing the terminal voltage of the generator, and undercharging is unlikely, unless the charging contacts are poor, because a large percentage of the charge is taken during the first few hours, after which the rate tapers rapidly until toward the end it amounts to only a trickle charge. Where this method is employed the terminal voltage of the generator should be set at the value recommended by the battery manufacturer.

Whether a lead-acid battery is charged from a constant-potential or a constant-current supply the state of charge can be determined from specific-gravity readings. With the battery discharged the gravity will read approximately 1.150 and when fully charged, from 1.280 to 1.300. The best indication

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of state of charge, however, is obtained with the voltmeter. As with alkaline batteries, the idea is to reach and maintain a maximum-charge voltage. The voltage of a fully charged lead-acid battery will range from 2.40 to 2.50 volts per cell while on charge at normal charging rate.

Watering.- Batteries require water about once a week when in constant use. Use nothing but distilled water. Never fill cells above the proper level, for if filled too high the solution will be forced out during charge. When the valves of alkaline-type batteries are removed for the periodical watering they should be dropped into a pan of hot water. The carbonate that accumulates in the valves is readily soluble in the water, and the valves will thus be clean and in proper working order upon replacement. When the valves are replaced make sure that all seat properly. When the rubber-valve gasket is in good condition considerable force will be required to lock the valve in place. Always renew worn valve gaskets and tighten the pole-nut gaskets, renewing any of these found defective. These precautions are essential to prevent spilling of electrolyte. After the valves have been replaced it is a good policy to wash the top of each battery under a hot-water tap, pouring off any excess that might have been spilled into the battery casing. Where washing facilities are not available be sure there is no free electrolyte on the battery top or in the casing; then wipe all parts clean and dry. After the batteries have been watered they should be given a short brush-up charge.

Renewal of electrolyte.- The electrolyte in alkaline batteries is a solution of potassium hydroxide and a catalyst. Because of dilution and contamination it is desirable to renew the electrolyte every 8 to 12 months; specific-gravity readings taken to determine its condition have no value unless they are taken with the electrolyte at the normal level. Before solution is renewed discharge the battery to 0.5 volt per cell at normal rate, remove valves and valve gaskets, pour out half the solution, shake vigorously, and pour out the remainder. Never rinse cells with water. If rinsing is considered necessary use the old solution after straining to remove dirt. Never let the cells stand empty; refill them as quickly as possible with the solution recommended by the manufacturer. Inspect the valve and pole-nut gaskets to ascertain that all are leakproof. Wash the battery top under a hot-water tap, pouring off any excess water that might have run into the battery casing. Always use clean utensils when renewing solution; never use any that have contained lead battery acid. After solution is renewed give the batteries an overcharge at the normal charging rate before putting them back into service. Always insure that a battery is clean, dry, and fully charged before issuing it to a miner.

The electrolyte in the lead-acid batteries is sulphuric acid solution. Because of the relatively short life of lead battery plates renewal of the electrolyte usually is not necessary during the life of the plates.

Rejuvenation.- Owing to enforced periods of idleness, insufficient daily charge, trickle-charging, low temperatures, or contamination of electrolyte, alkaline batteries may lose capacity and become sluggish. Loss of

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capacity generally can be regained by subjecting the batteries to a rejuvenation process. The recommended procedure follows: Discharge the batteries by letting the bulbs burn in the headpieces until the voltage across the battery terminals with the bulbs drawing current reaches 0.5 volt per cell. Then short-circuit the batteries for several hours through low resistance - a short piece of no. 8 wire fastened securely to the terminal posts is suitable for the purpose. Finally give them an overcharge (normal rate of charge for several hours longer than normal). The batteries can then be put back into service but will not have normal capacity until they have been through several charge and discharge cycles. It is therefore better policy to discharge a battery and give it another overcharge, after short-circuiting before returning it to service. If no substantial improvement results from this process repeat it. As a last resort, if still no improvement is noted, change the solution as directed under renewal of electrolyte.

Lead batteries of the pasted-plate variety lose capacity owing to dislodgment of active material from the plates and by sulphation. The "Ironclad" type of positive plate in which the active material is held in horizontally slotted hard-rubber tubes was developed to forestall excessive dislodgment. More recently a battery that does not contain free electrolyte has been developed. In this battery the electrolyte is absorbed in thick sponge wood separators held close to the plates. This latter development eliminates the washing action of free electrolyte, which was the main cause of dislodgment of active material.

Some evidences of sulphation are: Continued low specific gravity; continued low open-circuit voltage; inability to take normal charge on account of increased internal resistance; and the light color of either or both positive and negative plates, the last being the best indication. Sulphation can be remedied, if it has not gone too far, by giving the battery several complete discharge (to 1.7 volts per cell) and charge cycles.

Headpieces

The headpiece houses the safety device and contains a switch, together with the bulb, reflector, and lens, all of which affect the efficiency of the lamp. The safety device embodies contacts that influence the resistance of the bulb circuit. The switch contacts usually are of the wiping variety designed to clean themselves automatically, but sometimes they become corroded or oxidized and the moving member occasionally works loose. The headpiece should be inspected periodically to insure that the contacts are clean and tight and all terminals soldered properly or fastened securely. The safety of the unit depends upon the bulb ejector; this should be checked to insure that it has not become blocked or otherwise made ineffective.

The maximum reflecting efficiencies of new headpieces of permissible cap lamps will range from 80 to 85 percent. Both the reflector and the lens absorb some of the light emitted by the bulb. It is important that these absorptions be kept as small as practicable; the headpiece should therefore be kept sealed and in its original permissible condition.

The miner should never have access to the interior of a headpiece, and no person should be authorized to make any alterations in a headpiece that will affect the distribution of light.

Bulbs

The approval of each permissible cap lamp covers one or more bulbs for use with that lamp. Approved bulbs are plainly marked with a Bureau of Mines symbol number at the base - BM-20C, BM-25B, etc. The numeral in each symbol is the approval number of the cap lamp, and the letter following the numeral denotes a modification of the originally approved bulb. Where more than one bulb has been approved for a lamp the current and voltage ratings of each are different although outwardly they are alike; the shape and size of the main bulbs of all cap lamps in this country are uniformly the same.

A 1.0-ampere bulb which operates satisfactorily on a new battery may be too heavy a drain on a depreciated battery, in which case a lower-current bulb is sometimes substituted, with a corresponding loss of light. If the higher-current bulb is used more light is emitted in the early part of the shift but little or no light at the end. However, before changing to lower-current bulbs the real cause of any diminution of normal amount of light should be determined. It is important to know whether the cause is normal deterioration of the battery or some correctable condition, such as poor condition of the bulb or reflector or external resistance. It may not be necessary to substitute lower-current bulbs, and the advantage of the increased light given by the higher-current bulb will be retained.

All approved bulbs have met the Bureau's requirement of at least 200 hours' life. One make of permissible cap lamp contains 2 bulbs, 1 of which is an auxiliary bulb of the flashlight type for emergency use. The major bulb used in this lamp has 2 similar filaments, the aggregate life of which is the required 200 hours. Other permissible cap lamps are equipped with 1 double-filament bulb having 1 major and 1 minor filament; the life of the major filament must be 200 hours. No requirements are made for the life of the minor filament, because this filament is primarily for emergency use.

It is suggested that 1 filament of the double major-filament bulb be burned for approximately 100 hours and then the second filament switched on before the first was burned out so that the miner may have normal light to finish his working shift when the second filament burns out.

The end of a bulb's useful life usually is less than its ultimate or "burn-out" life. Blackening of the bulb glass indicates the end of useful life. It represents a loss of material from the filament; which becomes smaller and has higher resistance than when new; consequently the bulb draws less current from the battery and gives less light. Blackening also causes a loss of light through the bulb glass. Thus, toward the end of its life a cap-lamp bulb may give 30 percent less light than when it was new. If, as generally agreed, a worker's efficiency and safety depend to a great extent upon the amount and quality of light available, using cap-lamp bulbs until they burn out is not real economy.

Reflectors

Shape, finish, and position of reflector are the main factors that determine distribution of light. Reflectors that give the most desirable distribution underground are of the diffusing type. No certain type is compulsory, but since the desired distribution of a diffused light is produced so readily by the diffusing type of reflector it has been adopted in all permissible cap lamps in use today. All reflectors of permissible cap lamps are made of aluminum and have a mat finish produced either by sand-blasting or by a chemical treatment. Two modifications of permissible electric cap lamps equipped with polished, plated-brass reflectors have been approved for limited use in inspection service, but these are special lamps with special approvals and are not covered by the regular cap-lamp schedule.

Mining men are continually attempting to improve their lights by altering the original reflector finish. The most common practice is to rub the reflecting surface with a fine abrasive to obtain a polished finish. The popular opinion seems to be that when the light is concentrated into a small spot it has been improved. The spot produced only appears brighter in contrast to the dimmer light surrounding it but actually is not as bright as the central area of the field produced by a standard diffusing reflector. One outstanding case has been called to the Bureau's attention. This reflector had been given a coat of black enamel which resulted in a reddish-black, glossy finish. The glossy finish had the effect of producing a field somewhat similar to that produced by a highly polished reflector - a bright central spot surrounded by an area of dim light - and permitted only about 35 percent of normal illumination. This case is unusual, but it serves to show how far the miner, usually not versed in the subject of illumination, can be misled in his efforts to improve his light. The individual who made that change actually believed he had improved his light. He probable sought a softer light, but he actually subjected himself and his fellowworkers to constant danger and glare in traveling and working under the poor light he produced for himself by altering his cap-lamp reflector.

As has been stated, these "improvements" usually result in a loss of light. There is no perfect reflector, one that reflects 100 percent of light emitted by the bulb. Those furnished with permissible cap lamps have been developed in laboratories where all facilities necessary to determine the proper features are available. To alter the reflectors is to defeat the purpose of all this work.

Standard permissible cap-lamp reflectors absorb 10 to 15 percent of the light produced by the bulb. Scratched or soiled reflectors may absorb as much as 30 percent of the light and reflectors that have been rubbed, as much as 40 percent. Hence, the reflector accounts for a loss of 20 to 30 percent of the total available light.

These excessive losses result in low efficiencies, which can and should be avoided. Refinishing in the field is not satisfactory; reflectors that have become soiled or scratched should be replaced and returned to the lamp distributor, who has facilities for restoring the original finish. Changing the finish of the reflector is the most common alteration of the permissible cap lamp at the mines and should be strongly discouraged.

Polished reflectors have not been approved for use in permissible cap lamps because they do not distribute the light to the best advantage of the average miner in the performance of his regular duties. However, the Bureau is aware that many polished reflectors are being used today - too many, in fact. Some operators believe that certain duties in a mechanized mine require concentrated light. For such work as haulage and operation of cutting or loading machines in especially dusty atmospheres or for the purpose of signaling it is perhaps aafer to use the concentrated light as produced by the polished reflector. On the other hand, the average miner should not be permitted to use one. In the first place it produces excessive glare, causing discomfort to the eyes and temporary blindness for an instant or so, the space of time in which accidents usually occur. In the second place the polished reflector absorbs more light than the standard diffusing type and therefore reduces cap-lamp efficiency. The finish of some polished reflectors deteriorates more rapidly than that of the diffusing types; consequently the light in the outer portion of the field soon diminishes to a point where an inadequate walking light is produced.

It is well to remember that a cap lamp equipped with a polished reflector is not permissible. If steps were taken to allay the dust caused by mechanical operations in rooms, rather than resorting to the use of polished reflectors, several hazards might be eliminated instead of another created through glaring lights. More efficient locomotive headlights or stationary illumination for track and switches would relieve the need of spotlights for snappers.

Lenses

Any lens will absorb some of the light emitted by the bulb. Lens supplied with permissible cap lamps are made of clear glass 0.060 to 0.1 inch thick with plain surfaces. This type was selected because of its low coefficient of absorption. The maximum amount of light absorbed usually is less than 5.0 percent. These original lenses have been replaced by many other types in attempts to improve the light. As when the reflector finish is altered, the "improvement" usually results in loss or undesirable distribution of light.

Three-ply "safety-glass" lenses, the central ply of which is a cellulose compound, have practically the same coefficient of absorption when new as standard lenses, but as the cellulose compound oxidizes and causes it to turn yellow the absorption increases. This type of lense once was used in permissible cap lamps and is now used by the British in headpieces without safety devices. Safety-glass lenses are still available, but their use is not recommended because of deterioration, which results in a gradual loss of efficiency; incidentally, no particular advantage in safety is gained.

At certain mines a concavo-convex lens, clear in the center with a rough beady finish 5/16 inch wide around the outer edge, has been substituted under the assumption that it improves the light, whereas it actually absorbs over 2.5 percent more light than a standard lens. The plano-convex type as used in some flashlights also has been adapted to cap lamps. This lens in a headpiece equipped with a standard diffusing reflector produces a small concentrated area or spot. This type absorbs an excessive amount of light and produces very undesirable distribution; it increases the area illuminated yet decreases the area of adequate illumination, because the light thrown beyond 130° is wasted and the increase in light in the center is gained at the expense of illumination outside the center. The double convex and the concavo-convex lenses give results similar to those of the plano-convex lens.

A "daylight" lens was developed for men working at picking tables to enable better differentiation between the coal and slate. It produces a blue light, which has the same effect as sunlight with respect to reflection of colors as seen by the eye. However, when a daylight lens is used for proper selection of color the amount of light must be increased in proportion to the absorption coefficient of the blue glass used to produce it. This cannot be done advantageously in the cap lamp, owing to the limiting conditions; what might be gained in color perception is lost in quantity of light, making the daylight blue lens impracticable for use in the cap lamp. This lens did not affect distribution of light appreciably but absorbed almost 25 percent more light than a standard lens.

Cords

The cord or cable conducts the electrical energy from the battery to the headpiece. Flexible rubber-covered cords that have proved their practicability with respect to carrying capacity and mechanical strength are supplied with permissible cap lamps. The average life of cap-lamp cords is estimated at approximately 8 months. The strands ultimately break through corrosion and flexing; broken strands reduce the carrying capacity of the conductor and set up resistance to the flow of electricity from the battery which reduces the voltage across the bulb terminals. Usually the battery electrolyte creeps under the insulation and causes corrosion; this creepage can be prevented by sealing the ends of the cord with pitch compound. Perspiration also causes some corrosion but mainly swelling and deterioration of the rubber insulation. Swelling of the cord sheath destroys the binding effect of the insulation, making the copper strands more susceptible to breakage due to flexing.

Cables should be given more attention than is generally believed necessary and replaced or serviced when found defective. When corrosion has started at the battery end of a cable that end should be cut off, but if discovered early it should not be necessary to cut off more than a half inch. The end can be cut several times, or until the cable has become too short. Terminal lugs should always be resoldered. Corrosion of terminals can be kept at a minimum by preventing electrolyte from getting into the battery cover. One manufacturer has considered this in the design of his battery and piped the gas formed in charging to the outside of the battery. In lamps that have removable covers the plate terminals should be kept tight and valves should be kept in good working order. Any electrolyte that passes through valves that are normally open during a charge or any spillage during filling should be washed off.

Contacts

The importance of keeping external resistance in the electrical circuit at a minimum cannot be stressed too strongly. Loose, dirty, or corroded contacts also cause resistance in the circuit. All lugs, etc., that normally are soldered should be soldered if replaced. All contacts, both on top of the battery and headpiece, should be kept clean and tight. The carbonate that is deposited on the metal parts on top of the cells of alkaline batteries can be washed off under a hot-water tap. Abrasives should not be used for polishing contacts should be avoided, as most metal parts are plated and abrasives remove the plating.

Distribution of Light

The normal field of light from a permissible cap lamp may be divided into three areas. The first is a small, central area of concentrated light from the filament itself, which is normally in the center of the headpiece. This area, usually 6° to 8° in extent, is surrounded by a bright area approximately 20° in extent, which is bright enough to accommodate the performance of ordinary duties. These areas combined constitute the "working light." The rest of the light to the edge of the beam, the total angle of which is limited to 130°, is bright enough to permit safe traveling. This area is considered the "walking light." There are no sharp lines of demarcation between these three areas, the light of one shading into the next and giving a pleasing distribution with the minimum of annoying glare. Then, too, the entire field is free from dark spots or rings.

The useful product of an electric cap lamp is light. Almost every part of the lamp is closely related and bears on the amount or quality of the light and the general practicability of the lamp. Much research work has been done to obtain a desirable distribution of light from cap lamps for general service underground. Many lamp users in the field have attempted to improve this distribution of light, but the Bureau does not know of one that has been succesful. Usually such attempts result in less desirable distribution and glare, together with either an actual loss of light or a waste of available light. It is a waste of light to increase the light beam beyond an angle of 130° as any light beyond that angle is outside the normal field of vision and serves no useful purpose.

Conclusions

The Bureau of Mines became interested in electric cap lamps because it saw in them a safer and more efficient means of lighting mines than with open-flame lamps. The Bureau undertook the sponsorship not only of the safety but also of the practicability of electric cap lamps in order that these lamps might be adopted as early and as widely as possible. The need for safe illumination still exists, as more than half of the miners in the United States still use open lights; the Bureau is still actively behind the further use of electric cap lamps.

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The operator should insist that his lamps be kept in good working order for three reasons: (1) Better lighting means greater safety to the user, fewer accidents, and less compensation for injuries; (2) better lighting pays in increased tonnage and cleaner coal; (3) if the lamps are not properly maintained they lose favor and their introduction is retarded.

The keyman in proper lamp maintenance is the lamp attendant. The operator can do much by selecting proper lamp attendants and in furnishing enough help and supplies to do the job adequately. The lampman should keep account of the repairs made on each lamp. Such an account will "show up" the careless or malicious user.

Observations and data of various lamp installations indicate that an attractive lamphouse, cleanly and neatly maintained, inspires careful use of lamps. In some places a system of prizes for exceptionally good care of lamps will help; in others a system of charging all breakage of lamps against the individual miner is more effective.

Each user should report any damage to his lamp, a burned-out filament, or any flickering of his light. Any just complaints should be given courteous attention by the lamp attendant.

The permissible cap lamp is an ideal source of illumination for the purpose intended. It follows each movement of the head, directing the light on the objective sought, and never causes a man to cast a shadow in the path of his light. It gives him light at his feet, which is essential for safe traveling, and yet does not waste light by throwing it outside his field of vision. Its primary purpose is to give adequate light and remove the hazards attending the use of open lights. A cap lamp in a permissible condition embodies all the features designed to accomplish that end.

Safety can be assured by keeping the battery cover and headpiece locked, sealed, or properly fastened in place, as the case may be, and all the parts in working order. Maximum efficiency can be maintained by keeping a close check on the condition of the battery, the bulb, and the reflector and current-carrying contacts.

The Bureau does not infer that permissible cap lamps are perfect or that the ultimate in safety or efficiency has been attained; as a matter of fact, cap lamps are continually being improved. Neither does it infer that the layman is incapable of improving a permissible cap lamp; many important developments have resulted from suggestions of the user in the field.

Before any contemplated alterations of permissible equipment are made it is recommended that the manufacturer be consulted. He will undoubtedly appreciate any practical suggestions for improvement in design or construction. The manufacturer of a cap lamp is the one to whom the Bureau of Mines approval is issued. Any changes made in a permissible cap lamp or any other piece of permissible electrical equipment, for that matter, must be initialed by him. He must then submit specifications of the proposed changes to the Bureau for an extension of his approval covering the proposed changes. Where safety or adequacy are involved further tests are made by the Bureau to insure adequate standards for permissible equipment.

It is hoped that this paper will encourage and stimulate a greater interest in maintenance of portable electric lamps and discourage the use of unapproved parts, which usually decrease the efficiency of the lamps and may result in a potential hazard.